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ABSTRACT

Claims that computers and other high technology can replace teachers and staff, thereby reducing educational costs, are unwarranted for several reasons. First, most cost analyses focus on hardware costs, which are not the major factor directing the cost of computer assisted instruction (CAI). Second, technology is more likely to change the skill mix of labor in education than to decrease the labor intensity. Third, studies of CAI effectiveness lead to a policy of integrating the computer with the teacher, not replacing the teacher. Finally, the cost of replacing a significant portion of teacher time with CAI is currently prohibitive. This paper includes 19 references. (LMM)

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CAN IMPLEMENTATION OF COMPUTERS BE JUSTIFIED ON COST-EFFECTIVENESS GROUNDS?

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In an era of retrenchment, declining enrollments, and criticism of "standard" solutions to educational problems, some have proposed substituting technology for traditionally labor-intensive functions. For example, Norris (1977, p. 451) proposed:

> We must assemble and configure our several technologies [computers, television, radio, film, videodisc, etc.] into a system that does what the present educational process does, but does it with capital-intensive, productive technologies, rather than trying to drive still harder a labor-intensive process that can at best only stagger under the loads of higher needs, higher expectations, and higher and higher costs.

In this paper we examine claims that technology can decrease educational costs--primarily by replacing teachers and other staff--and increase educational productivity. We find this argument to be misleading for several reasons. First, most cost analyses focus on hardware costs: these costs are not the major factor driving the cost of computer assisted instruction (CAI). Second, technology is more likely to change the skill mix of labor in education than to decrease the intensity of labor. Third, studies of the effectiveness of CAI lead to a policy of integrating the computer with the teacher, not replacing the teacher. And fourth, the cost of replacing a significant portion of teacher time with CAI is currently prohibitive.

COST ESTIMATES: ASSUMPTIONS AND VARIABLES

Because technological hardware is part of the proposed solution to education's ills, we might expect cost-effectiveness research to play an important role in this argument. However, systematic studies of the costs and benefits of implementing computers, either for management or instruction, have been rare. [For exceptions, see Levin and Woo, 1980; see Stakenas and Kaufman (1977) for a review and references. See also Jamison, Klees, and Wells (1978) for a study of the costs of media.] Rather, costs have been reported piecemeal, and almost without exception, cost studies have occurred independently of effectiveness studies.

Cost estimates are extremely variable. For example, the cost of certain hardware systems such as microcomputers range from $300 to $7000, depending on the make and configuration; time needed to produce an hour of instructional courseware varies anywhere from 50 to 500 hours, depending on its attributes; the cost of developing an hour of courseware varies between $300-$3000, depending on its requirements; the cost of CAI varies between $0.40 to $28.50 per student hour, depending on the hardware, courseware, number of students using it, and so forth. The cost of the Computer Curriculum Company's (CCC) time-sharing system with limited student time spent on drill and practice in basic skills was estimated by the company to be $50 per student year in 1977, while other estimates of the cost of CCC's system are on the order of $135 per student year. (These estimates are based on reports by Kearsley, 1977; Chambers and Sprecher, 1980; Avner, 1978; Hebenstreit, 1980; Magidson, 1978; Neuhauser, 1977; Sugarman, 1978; McKenzie, et al., 1978; Okey and Majer, 1976; Levin and Woo, 1980.)

The reason for such wide variance in cost estimates is that they are made on the basis of many but seldom stated assumptions. Three categories of assumptions have been identified by Kearsley (1977). The first category includes assumptions about the components of the computer system. These components include hardware (e.g., central processing unit, peripherals), software for operating the computer system (e.g., operating system, course authoring language, graphics, utility programs), telecommunications (e.g., transmission costs, digital data networks), operating costs (e.g., salaries of computer operators, programmers, managers, teaching assistants), and courseware development (author's time, cost of adjunct material, evaluation).

The second category includes assumptions about the rate of use of the system such as the number of students served (e.g., per day, week, month, semester), the length of the school day and year, the amount of time, and the number of sites at which the system will be used. The third category includes assumptions about the life span of the system and courseware (e.g., three to five years for hardware, as much as ten years for basic skills software and a much shorter life for other courseware).

These cost assumptions are affected by a number of additional variables. Some of the more important variables are the type of CAI system (large scale mainframes, time-sharing minicomputers, stand-alone microcomputers), type of student (e.g., handicapped, bilingual, professional, adult/vocational), grade level (elementary, secondary, post-secondary), type of instruction (drill and practice, tutorial, simulation) and quality of courseware (e.g., extensive graphics, audio, enrichment sequences, alternative levels of difficulty, record keeping).

In general, most estimates focus on the costs associated with hardware and assume the other costs to be associated with normal school operations. This clearly underestimates the cost of implementing computers for instructional use, management use or both. Also, the cost analysis focuses on what might be the least expensive item, the hardware. Levin and Woo (1980) in their cost analysis of a time-sharing system, reported that

> The annualized costs of all the computer equipment including the terminals represented only about 28 percent of total annualized costs.... This means that even a rather drastic reduction in the 28 percent of the cost accounted for by equipment will amount to a much smaller reduction in the total cost. For example, if the cost of equipment declined by one third, total costs would decline by less than ten percent. At the same time, the costs of personnel, maintenance, construction and other personnel intensive categories are rising rapidly, at least offsetting partially the potential declines in the cost of computer hardware. Accordingly, it is important to recognize that there will be inherent limits to cost reduction for CAI, even with rapid technological improvements in hardware (1980, pp. 25-26, italics ours).

While the argument for shifting education from a labor-intensive toward a capital-intensive concern is compelling, upon closer examination such a policy may affect the skill mix of personnel in education as much as the mix of labor and capital. That is, a reduction in teaching

and related staff might be accompanied by an increase in technical staff associated with computer operations. Before a policy to implement computers is adopted as a solution to some educational problems, a more thorough study of the costs associated with such a policy is needed. Such a study would explicitly deal with the assumptions of costs outlined above, taking into account retrenchment, declining enrollments, and projections of hardware, courseware, and personel 10 to 15 years into the future.

EFFECTIVENESS OF COMPUTER ASSISTED INSTRUCTION

A policy to implement computers, however, rests on grounds in addition to cost. One immediate consideration is the effectiveness of CAI relative to alternative forms of instruction for reaching certain goals (e.g., basic skills, problem solving in science). There is an ever-increasing number of studies of the effectiveness of CAI. Many of these studies still pit the computer against the classroom teacher in a horse-race type of an evaluation. The results of such evaluations lead to the following conclusions for college students (Kulik, Kulik and Cohen, 1980): (a) a small difference in student achievement favoring CAI. Overall, "the effect of CBI [computer based instruction] in a typical class was to raise student achievement by one-quarter of a standard deviation unit" (p. 534); (b) a small difference in student attitudes favoring the computer (less than one-quarter of a standard deviation unit); (c) a strong advantage for the computer in the amount of time (less) needed for instruction; and (d) no difference in the number of students who complete the course of instruction (Kulik, Kulik and Cohen,

1980). However, it should be pointed out that these findings were aggregated over 59 studies. There was variability in the magnitude and direction of achievement and attitude outcomes from one study to the next. Finally, studies of elementary and secondary students who receive CAI (drill and practice) as a supplement to regular classroom instruction have found that student achievement is greater than that in conventional supplemental instruction (for reviews, see Vinsonhaler and Bass, 1972; Edwards, et al., 1975; Jamison, et al., 1974).

Horse-race evaluations are not particularly informative. Effectiveness studies should identify instructional goals, alternative instructional delivery systems, and valid measures of the outcomes. Seldom will this approach lead to a two-horse race. Rather, it will lead to findings which indicate those goals for which certain types of CAI for certain types of students are particularly effective and those goals for which they are not (Leiblum, 1981).

NEED FOR COST-EFFECTIVENESS STUDIES

Both the "cost" and "effectiveness" variables need to be more thoroughly defined and examined in conjunction with each other. Currently, what serves as a basis for estimating cost-effectiveness is a review of cost studies, a review of effectiveness studies, and an inferential leap regarding the cost-effectiveness of the two combined (e.g., Stakenas and Kaufman, 1977). The overall conclusion drawn from such studies is that computer-assisted instruction is not cost-effective (e.g., Butman, 1973). As might reasonably be expected, however, the effectiveness of CAI depends on the quality of the courseware, the

students served, the type of CAI used (e.g., drill and practice, tutorial, simulation), the nature of the instructional goal, and so on. Until methodologically adequate cost-effectiveness studies of alternative teacher-computer mixes are examined for various educational goals and student populations, arguments for implementing computers on cost-effectiveness grounds are specious.

CONCLUSIONS

Claims that computers and other high technology can replace teachers and staff, and by doing so reduce the costs of education, are unwarranted. We arrive at this conclusion for several reasons. First, these claims rest, at best, on inadequate studies of cost. Cost studies of CAI seldom cover the range of variables that drive cost. For this reason, cost estimates vary tremendously from one study to the next. Since the assumptions in estimating costs are seldom made explicit, the observed variability cannot be accounted for adequately.

Second, most studies focus on the cost of hardware rather than on human capital variables which actually drive the cost of CAI. This leads us to suspect that a policy of replacing teachers and staff is less likely to decrease labor costs than to change the skill mix of the staff by hiring computer programmers and the like.

Third, research on the effectiveness of CAI indicates that drill and practice as an adjunct to or alternative to some regular instruction is effective. This finding leads us to conclude that a policy of

integrating the computer with the teacher, rather than replacing the teacher, is more likely to lead to improved achievement in less time.

Finally, even with decreasing hardware costs, the costs of CAI are too great and the availability of quality courseware is too limited for a policy of replacing labor with capital to be realistically implemented, even if it were valued.

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